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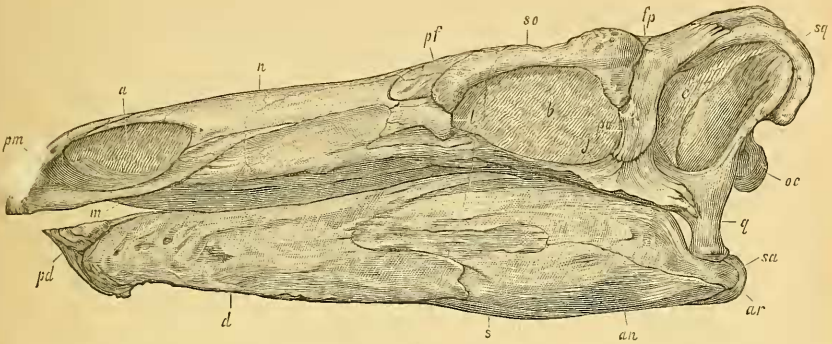

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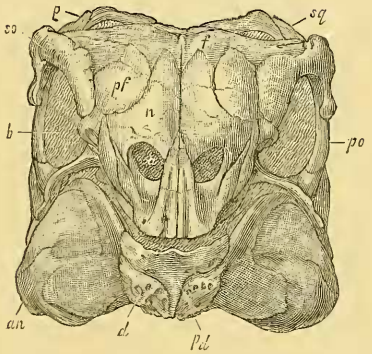

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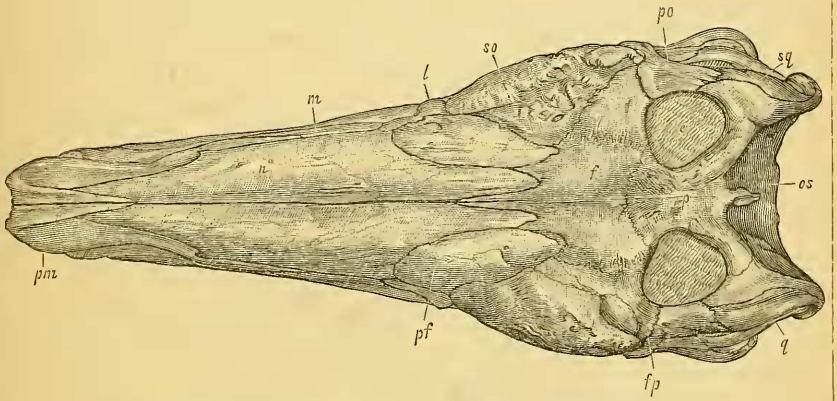


FIG. 1.—Skull of *Stegosaurus stenops*, Marsh; side view.
FIG. 2.—The same specimen; front view.
FIG. 3.—The same specimen; top view.
All the figures are one-fourth natural size.

From the Atlantosaurus Beds of the Upper Jurassic, Southern Colorado.

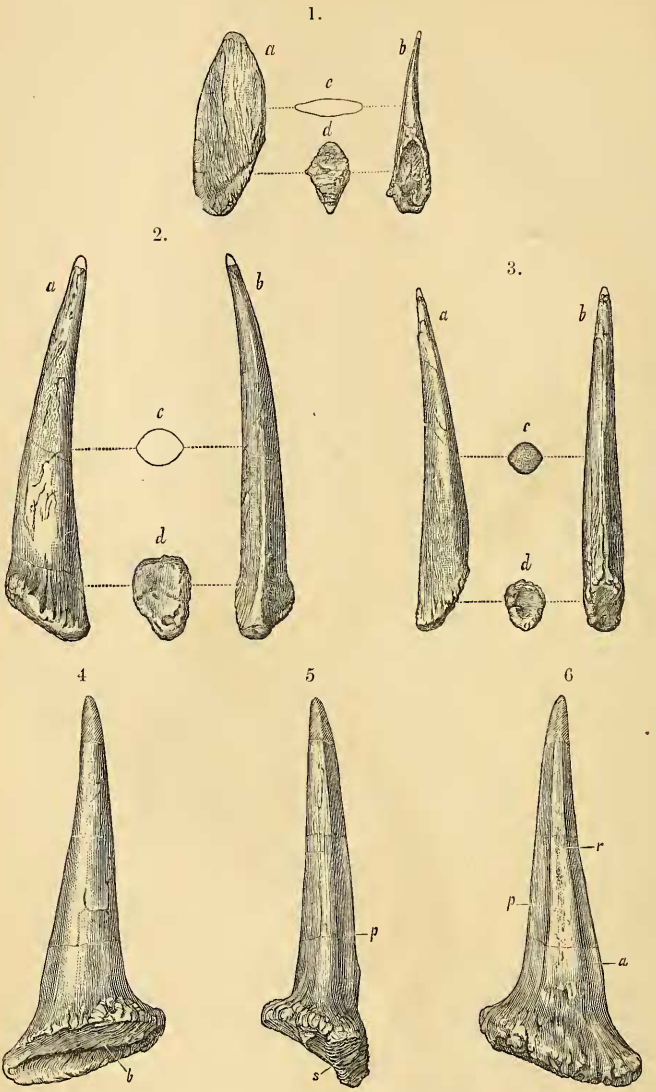


FIG. 1.—Dorsal spine of *Stegosaurus ungulatus*, Marsh; *a*, side view; *b*, posterior view; *c*, section; *d*, inferior view of base.

FIG. 2.—Large caudal spine of same individual; *a*, side view; *b*, front view; other letters as above.

FIG. 3.—Smaller caudal spine of same individual; *b*, posterior view; other letters as above.

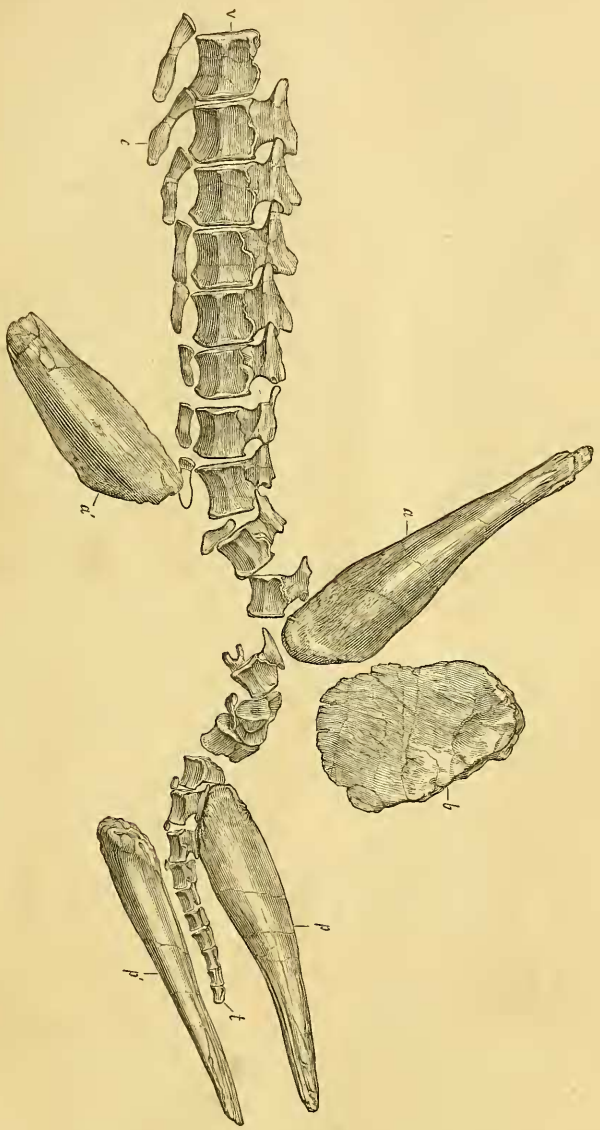
FIG. 4.—Caudal spine of *Stegosaurus sulcatus*, Marsh; side view.

FIG. 5.—The same spine; posterior view.

FIG. 6.—The same spine; inner view.

All the figures are one-twelfth natural size.

From the Atlantosaurus Beds of the Upper Jurassic, Southern Colorado.



Caudal vertebræ, spines, and plate of *Diracodon laticeps*, Marsh; seen from the left. One-sixth natural size. *a*, right anterior spine; *a'*, left anterior spine; *b*, small caudal plate; *c*, chevron bone; *p*, right posterior spine; *p'*, left posterior spine; *t*, terminal vertebra; *v*, median caudal vertebra.

From the Atlantosaurus Beds of the Upper Jurassic, Southern Colorado.

researches serves to convince us, however, that such rise of temperature is by no means a necessary prelude to a volcanic outburst, but that the percolation of water to a centre of igneous activity is in itself sufficient to serve as an exciting cause. If we were to imagine a mass of solid nitre lying at some depth within the earth's crust, and having a temperature of 260° C., such a mass would be solid and inert. But if, without raising the temperature, a quantity of water, equal to five per cent. of the weight of the nitre, were introduced into it, then the whole would become liquid and the tendency of the heated water to relieve itself from the pressure might give rise to all the phenomena of a volcanic outburst. What is true of nitre is equally true of the mixed silicates composing lavas, which are at much higher temperatures. The admission of water to such a mass of mixed silicates at a temperature below its point of fusion would cause it to become liquid and thus give rise to the phenomena of eruption. In the case of the Krakatoa-lavas, the anhydrous varieties probably existed quite solid at tolerably high temperatures; but the gradual percolation of water into their mass (and the evidences of such percolation, are seen in the hydrated condition of the minerals composing it) would render the whole liquid, without the necessity for any rise in temperature.

II.—The Skull and Dermal Armour of *Stegosaurus*.

By Professor O. C. Marsh, Ph.D., LL.D.

(PLATES I. II. III.)

In various numbers of the "American Journal of Science," the writer has given the more important characters of the skeleton of the *Stegosauria*, and has indicated the relations of this group to the other known *Dinosauria*.[1] The discovery of additional specimens of *Stegosaurus*, one of them nearly complete, furnishes material to greatly enlarge our knowledge of the skull and dermal covering of this genus, and some of the new facts are given in the present article.

The results of the entire investigation of this group will be brought together in a monograph now in preparation, by the writer, for the United States Geological Survey. The lithographic plates for this volume, sixty-five in number, are nearly all printed, and the figures of the skull here given are taken from these plates.

The Skull. (Plate I.)

The skull of *Stegosaurus* is long and slender, the facial portion being especially produced. Seen from the side, with the lower jaw in position, it is wedge-shaped, with the point formed by the premaxillary, which projects well beyond the mandible, as shown in Fig. 1, Plate I. The anterior nares (*a*) are large, and situated far in front. The orbit (*b*) is very large, and placed well back. The

[1] "American Journal of Science," vol. xiv. p. 513, Dec. 1887; vol. xix. p. 253, March, 1880; vol. xxi. p. 167, Feb. 1881; vol. xxiii. p. 83, Jan. 1882; and vol. xxiv. p. 410, Nov. 1887.

lower temporal fossa (*c*) is somewhat smaller. All these openings are oval in outline, and are on a line nearly parallel with the top of the skull. In this view, the lower jaw covers the teeth entirely.

Seen from above, as shown in Fig. 3, Plate I., the wedge-shaped form of the skull is still apparent. The only openings visible are the supra-temporal fossæ (*e*). The premaxillary bones (*pm*) are short above, but send back a long process below the narial orifice. The nasal bones (*n*) are very large, and elongate. They are separated in front by the premaxillaries, and behind, by anterior projections from the frontal bones. The prefrontals (*pf*) are large, and are placed between the nasals and the prominent, rugose supra-orbitals (*so*). The frontals are short, and externally join the post-frontals (*fp*). The parietals are small, and closely coössified with each other.

Viewed from in front, the skull and mandible present a nearly quadrate outline (Pl. I. Fig. 2), and the mutual relations of the facial bones are well shown. In this view is seen, also, the predentary bone (*pd*), a characteristic feature of the mandible in this genus. The lateral aspect of this bone is shown in Fig. 1.

The teeth in this genus are entirely confined to the maxillary and dentary bones, and are not visible in any of the figures here given. They are small, with compressed, fluted crowns, which are separated from the roots by a more or less distinct neck. The premaxillary and the predentary bones are edentulous.

The present skull belongs to the type specimen of a very distinct species, which the writer has called *Stegosaurus stenops*. The skull and nearly complete skeleton of this specimen, with nearly all the dermal armour in place, were found almost in the position in which the animal died.

This animal was much smaller than those representing the other species of this genus. Its remains were found in the Atlantosaurus beds of the Upper Jurassic, in Southern Colorado. In this geological horizon, all the known American forms of *Stegosauria* have been discovered.

The Dermal Armour.

The osseous dermal covering of *Stegosaurus* was first described by the writer from specimens found associated with several skeletons, but not in place, and hence the position of the various parts was a matter of considerable doubt. Subsequent discoveries have shown the general arrangement of the plates, spines, and ossicles, and it is now evident that, while all the group were apparently well protected by offensive and defensive armour, the various species, and perhaps the sexes, differed more or less in the form, size, and number of portions of their dermal covering. This was especially true of the spines, which are quite characteristic in some members of the group, if not in all.

The skull was evidently covered above with a comparatively soft integument. The throat and neck below were well protected by small, rounded and flattened ossicles having a regular arrangement in the thick skin. One of these ossicles is shown in Woodcut Fig. 1.

The upper portion of the neck, back of the skull, was protected by plates, arranged in pairs on either side. These plates increased in size farther back, and thus the trunk was shielded from injury.

Fig. 1.—Gular plate of *Stegosaurus ungulatus*, Marsh; *a*, superior view; *b*, side view; *c*, inferior view.

From the pelvic region backward, a series of huge plates stood upright along the median line, gradually diminishing in size to about the middle of the tail. One of these is shown in Woodcut Fig. 3.

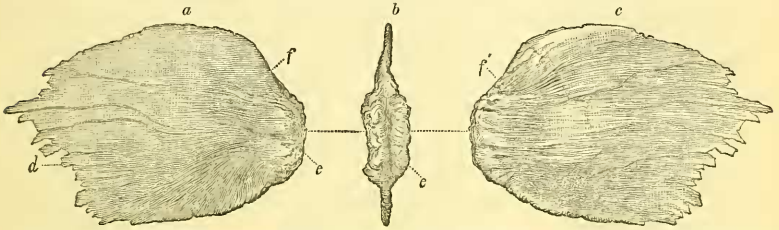


Fig. 2.—Caudal plate of same individual; *a*, side view; *b*, end view of base; *c*, view of opposite side; *d*, thin margin; *e*, rugose base; *f*, and *f'*, surface marked by vascular grooves.

Some of the species, at least, had somewhat similar plates below the base of the tail, and one of these bones is represented in Woodcut Fig. 2.

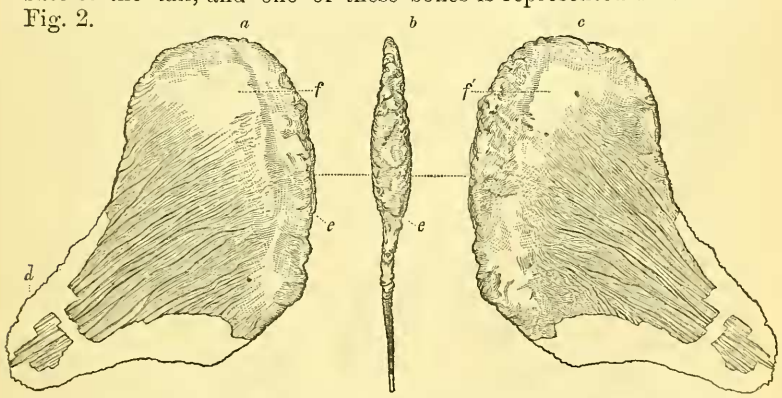


Fig. 3.—Dorsal plate of same individual; *a*, right side; *b*, thick basal margin; *c*, left side; other letters as in last figure.

All the figures are one-twelfth natural size.

The offensive weapons of this group were a series of huge spines arranged in pairs along the top of the distal portion of the tail, which was elongate and flexible, thus giving effective service to the spines, as in the genus *Myliobatis*.

In *Stegosaurus ungulatus*, there were four pairs of these spines, diminishing in size backward. Two of the larger of these are

shown on Pl. II. Figs. 2 and 3. In some other forms there were three pairs, and in *S. stenops* but two pairs have, as yet, been found.

In one large species, *Stegosaurus sulcatus*, there is at present evidence of only one pair of spines. These are the most massive of any yet found, and have two deep grooves on the inner face, which distinguish them at once from all others known. One of these grooved spines is represented on Pl. II. Figs. 4, 5, and 6.

The position of these caudal spines with reference to the tail is indicated in the specimen figured on Pl. III., which shows the vertebræ, spines, and plate, as found.

The American genera of the *Stegosauria* now known are *Stegosaurus*, *Hypsirhophus* and *Diracodon*. Of the former there are several well-marked species besides *S. armatus*, the type. Of the latter genus but one is known at present, *Diracodon laticeps*, the remains of which have hitherto been found in Wyoming at a single locality only, where several individuals referred to this species have been discovered. Aside from the form of the skull, these specimens have in the fore foot the intermedian and ulnar bones separate, while in *Stegosaurus* these carpals are firmly coössified.

All the known American forms appear to have the second row of carpals unossified, and five digits in the manus. In the hind foot, the astragalus is always coössified with the tibia, even in very young specimens, while the calcaneum is sometimes free. The second row of tarsals is not ossified in any of the known specimens. Only four digits in the hind foot are known with certainty, and one of these is quite small. All forms have at least three well-developed metatarsals, which are short and massive, but longer and much larger than the metacarpals. Most of the bones originally referred to the hind foot of *Stegosaurus ungulatus*, and figured as such (Amer. Journ. Sci. vol. xxi. pl. viii.), although found with the posterior extremities, subsequently proved to belong to the fore foot of another larger species.

In one large specimen, of which the posterior half of the skeleton was secured, no trace of dermal armour of any kind was found. If present during life, as indicated by the massive spines of the vertebræ, it is difficult to account for its absence when the remains were found, unless, indeed, the dermal covering had been removed after the death of the animal, and previous to the entombment of the skeleton where found. In this animal, the ilia were firmly coössified with the sacrum, thus forming a strong bony roof over the pelvic region, as in birds.

This specimen represents a distinct species, which the writer has named *Stegosaurus duplex*. It was originally referred by him to *S. ungulatus*, and the pelvic arch was figured under that name.[1] In the sacrum of this species, each vertebra supports its own transverse process, as in the *Sauropoda*, while in *S. ungulatus* these processes have shifted somewhat forward, so that they touch, also, the vertebræ in front, thus showing an approach to some of the *Ornithopoda*.

The great weight of the armour in *Stegosaurus*, taken in connection

[1] Amer. Journ. Sci. vol. xxi. pl. vii. Feb. 1881.

with the massive and solid bones of the skeleton, and, especially, the enormous vertical extent of the compressed tail, indicate an aquatic life. This opinion was expressed by the writer in describing the first specimen found, and the discoveries since made have done much to confirm it. That these reptiles moved freely on land, also, is quite probable. Other genera of the group may have lived mainly upon the land.

The large number of specimens of the *Stegosauria* now known from the American Jurassic, and the fine preservation of some of the remains, enable us to form a more accurate estimate of the relations of the group to the other Dinosaurs, than has hitherto been possible. The presence of a predentary bone, and the well-developed post-pubis, are important characters that point to the *Ornithopoda* as near allies, with a common ancestry. These positive characters are supplemented by some points in the structure of the skull, and the form of the teeth.

There are, however, a large number of characters in which the *Stegosauria* differ from the *Ornithopoda*, and among these are the following :—

(1) All the bones of the skeleton are solid.
(2) The vertebræ are all biconcave.
(3) All the known forms have a strong dermal armour.
(4) The second row of carpals and tarsals are unossified.
(5) The astragalus is coössified with the tibia.
(6) The spinal cord was greatly enlarged in the sacral region.

The relations of these two groups to each other and to the rest of the known *Dinosauria* will be fully discussed by the writer in his monograph on the *Stegosauria*.

New Haven, Conn., *October*, 1887.

III.—On certain anomalous Organisms which are concerned in the Formation of some of the Palæozoic Limestones.

By H. Alleyne Nicholson, M.D., D.Sc., F.G.S.,
Regius Professor of Natural History in the University of Aberdeen.

THAT many of the Palæozoic limestones are more or less extensively composed of the skeletons of various Invertebrate animals, sometimes in a perfect condition, sometimes more or less largely fragmentary, has long been known. In certain instances a microscopic investigation of these ancient calcareous sediments may fail to demonstrate the presence of organic remains, or may reveal but few of these. Thus there occur beds of lithographic limestone in the Palæozoic series which would seem to be simply of the nature of very finely levigated calcareous mud, the component grains of which were, however, doubtless derived, in the first instance, from the calcareous skeletons of animals. Again, it commonly happens, even in examples where the rock may to all appearance be little altered, that a limestone may be found on examination by means of thin sections to have undergone secondary crystallization, with the result of a more or less complete obliteration of the organic remains